Testing Models of Binary Black Hole Mergers

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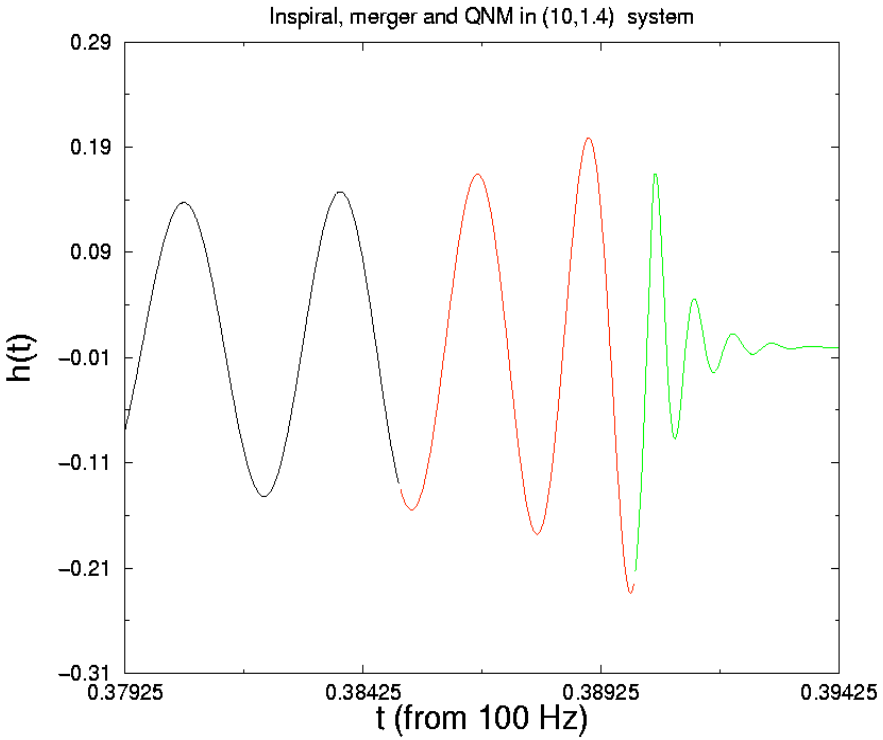
Testing the Merger Dynamics

- From inspiral, merger and quasi-normal modes
  - Test analytical models of merger and numerical relativity simulations
- Effective one-body (Buonanno and Damour)
  - 0.07% of total mass in GW
- Numerical relativity
  - 1-3% of total mass in GW
  - Phasing could be significantly different from EOB
- If we assume that numerical relativity is error free, test GR



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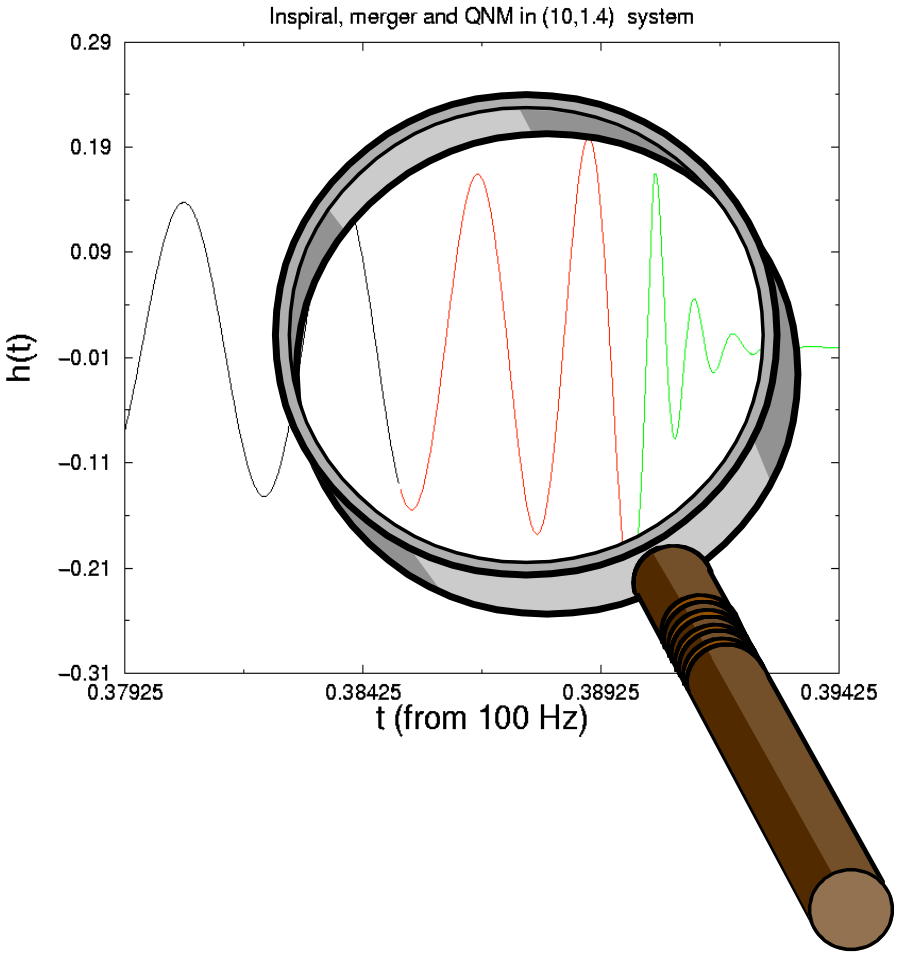
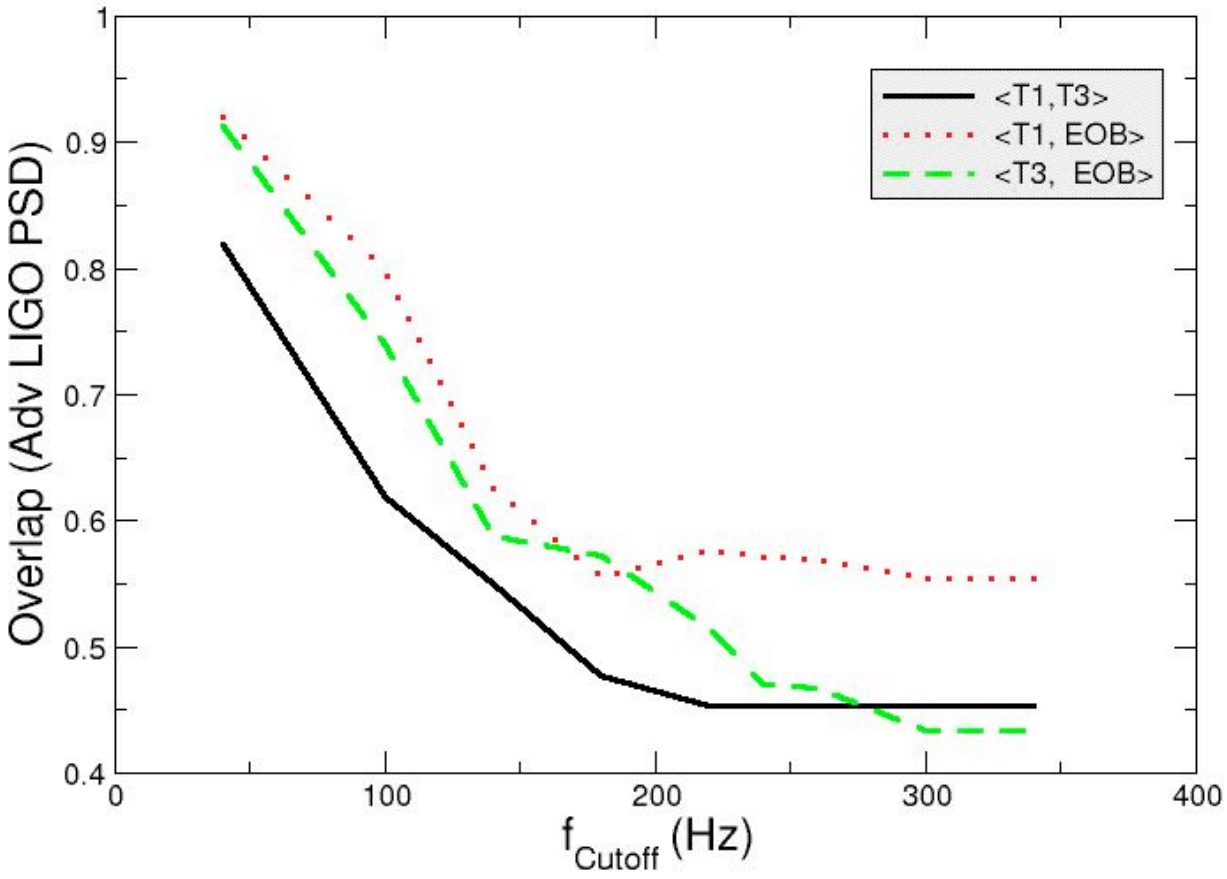


Model independent measurement of parameters from inspiral

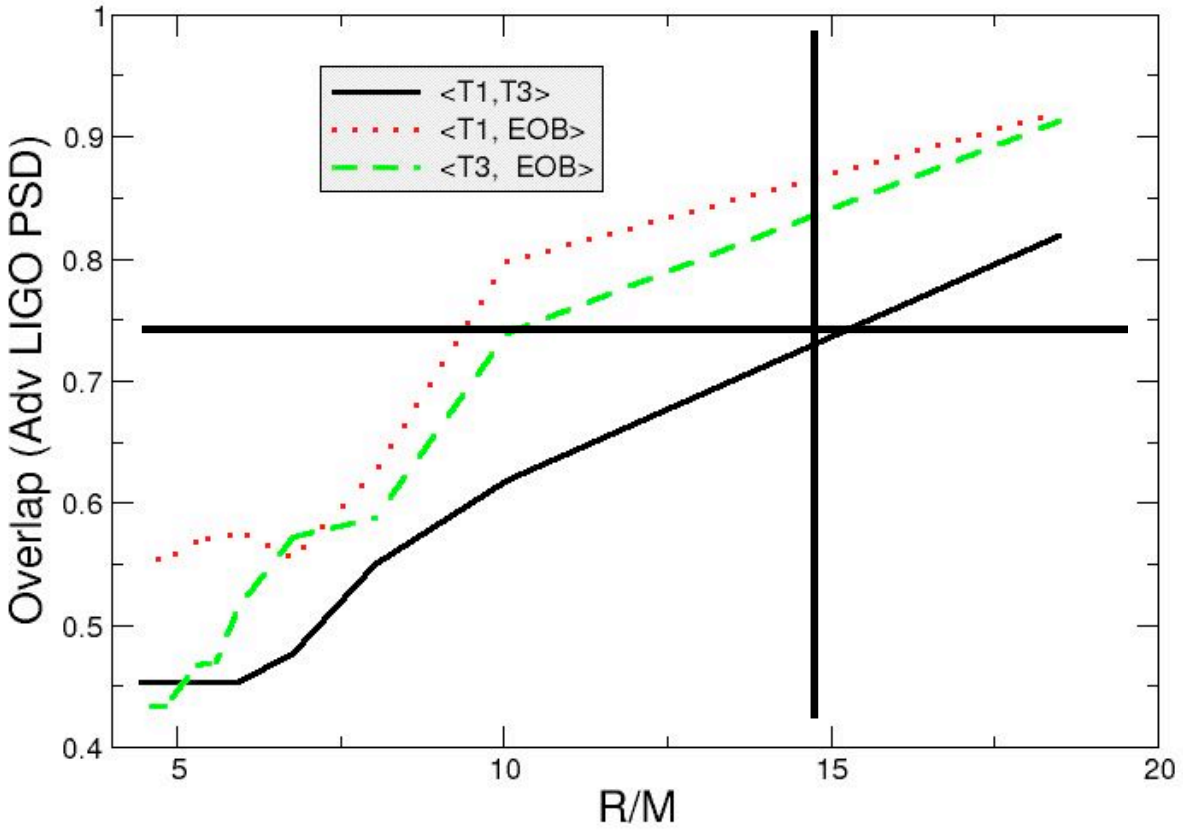
- At earlier times different post-Newtonian orders and different families agree with each other
- Once having detected a signal divide the data stretch into three pieces
  - Adiabatic region
    - The overlap between different families is better than 75%: apply a low-pass filter to select the relevant data segment
  - Non-linear regime
  - Ringdown region
    - **Don't know how to do this yet:** our work assumes that you somehow know how to do this.

How similar are the waveforms?



Measure the overlap of the waveforms weighted by the noise spectral density of the detector as a function of the upper-frequency cutoff

How similar are the waveforms?

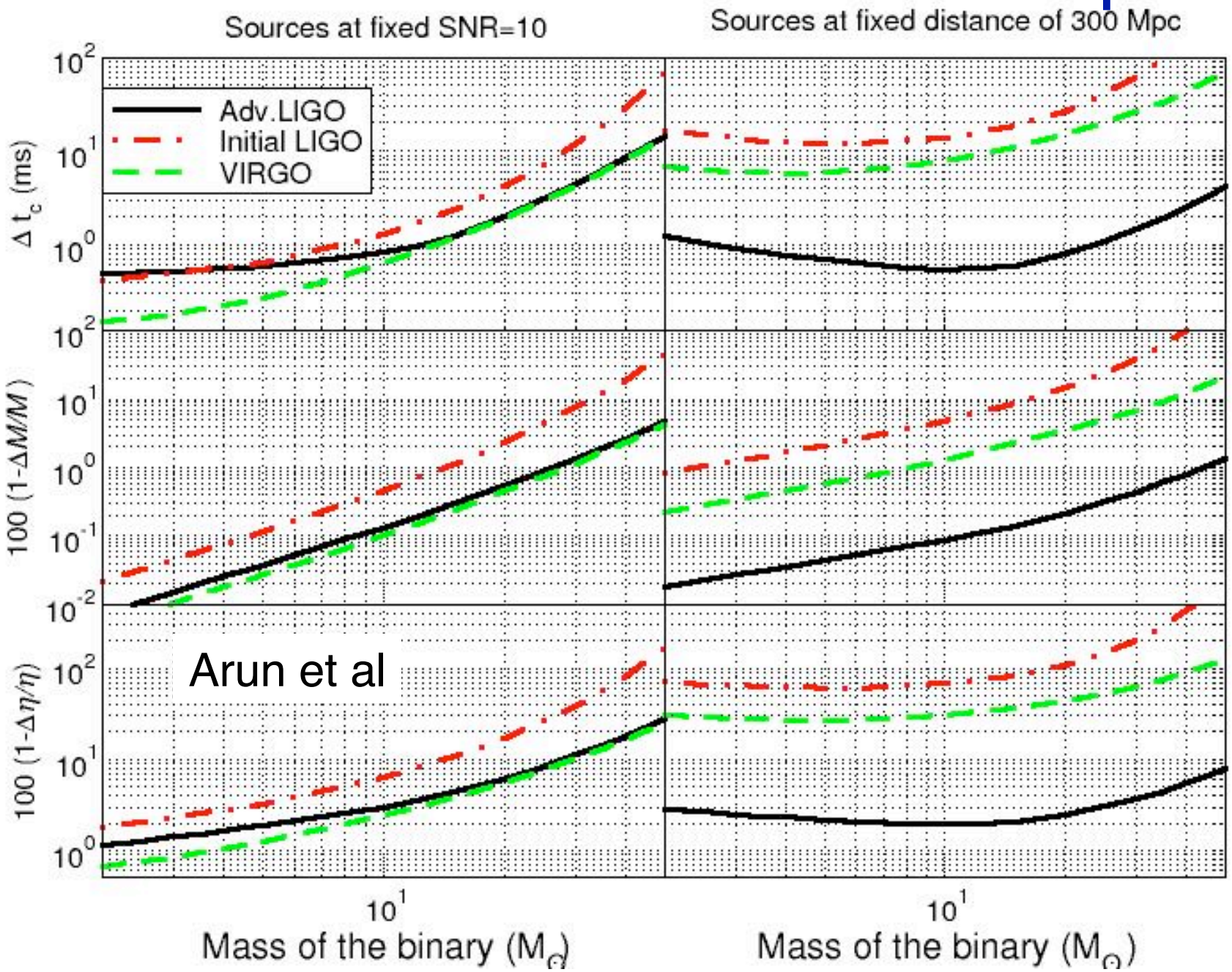


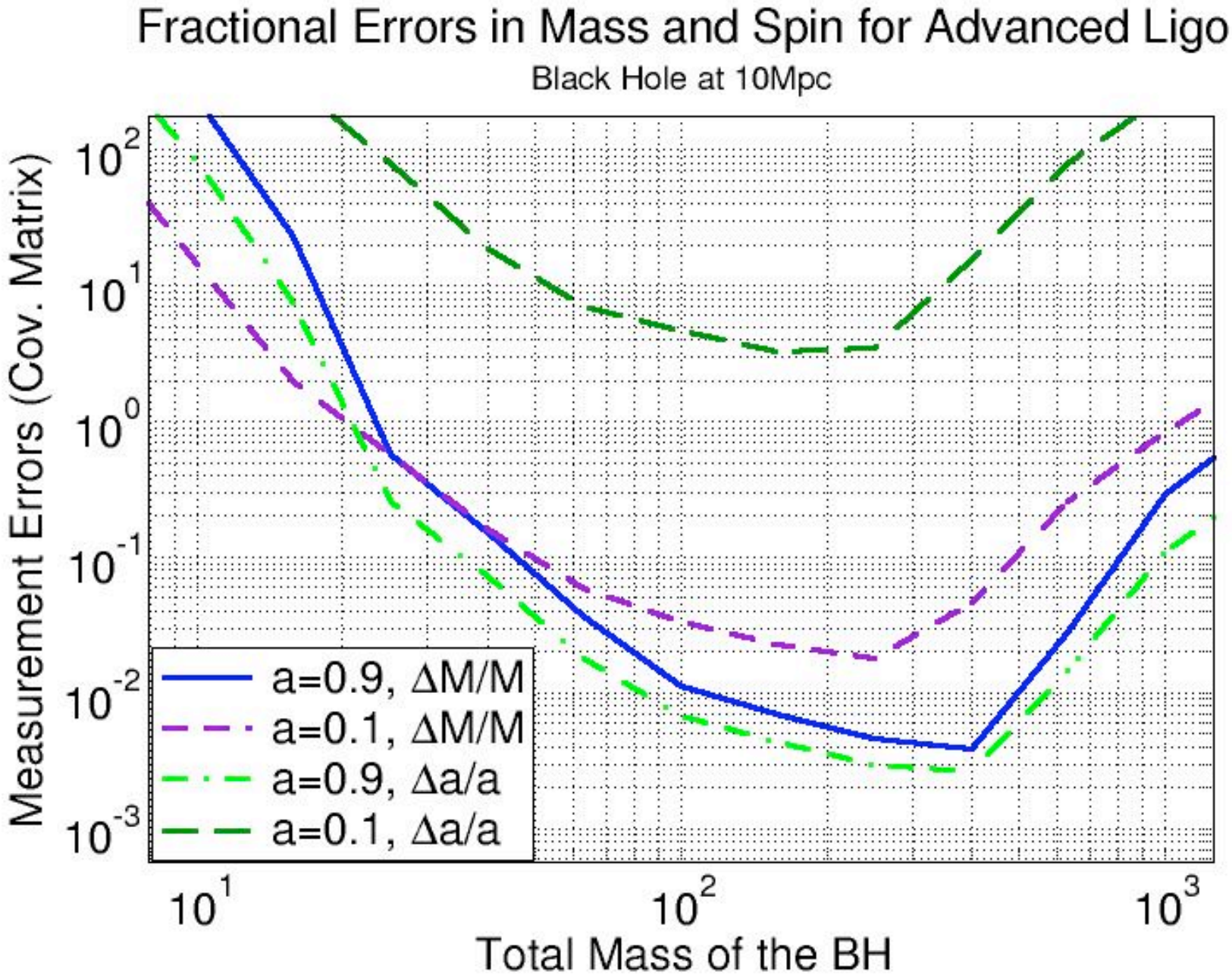
Based on these evaluations assume that the adiabatic phase is valid until about

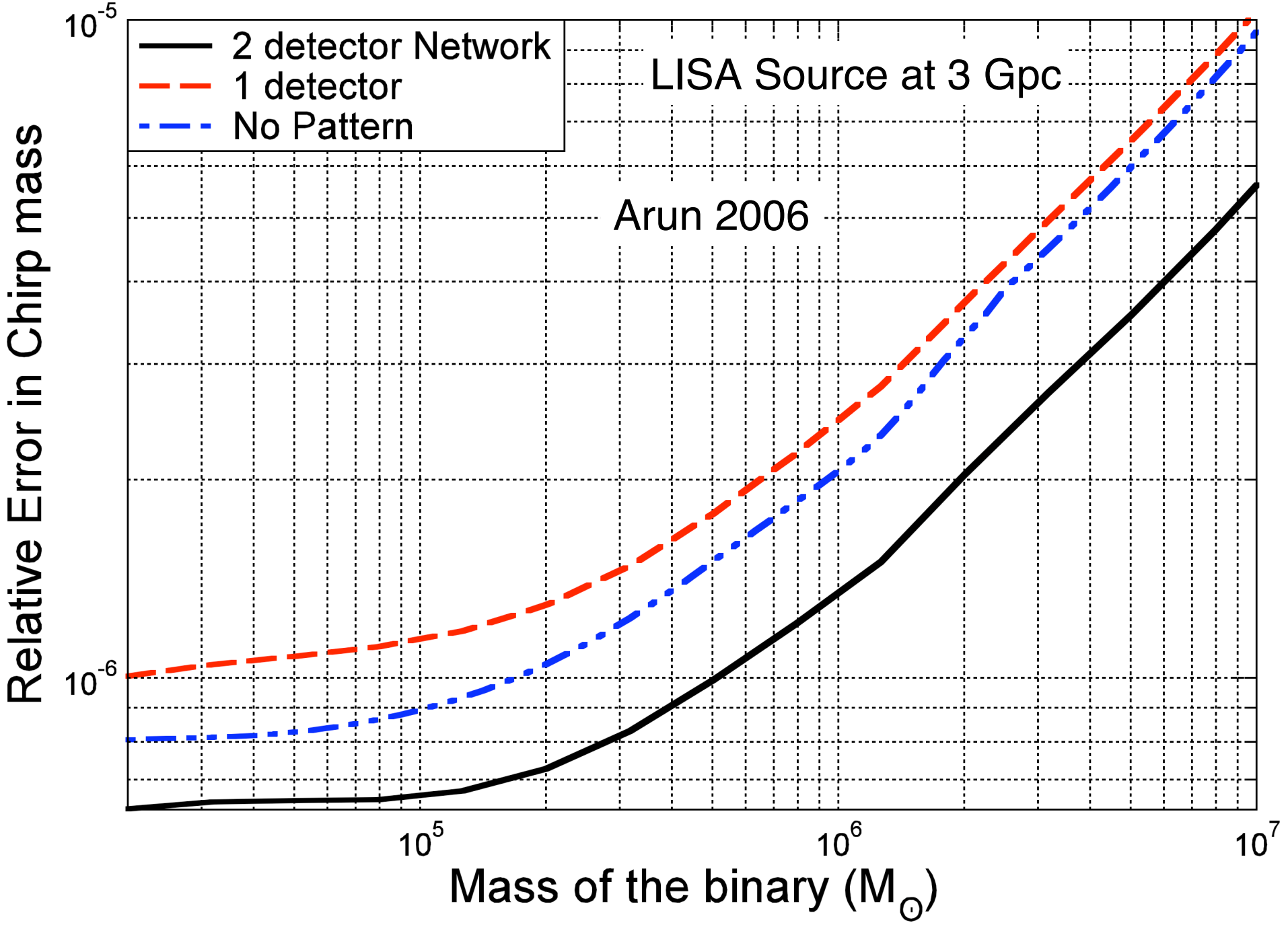
R~10-15 *M*

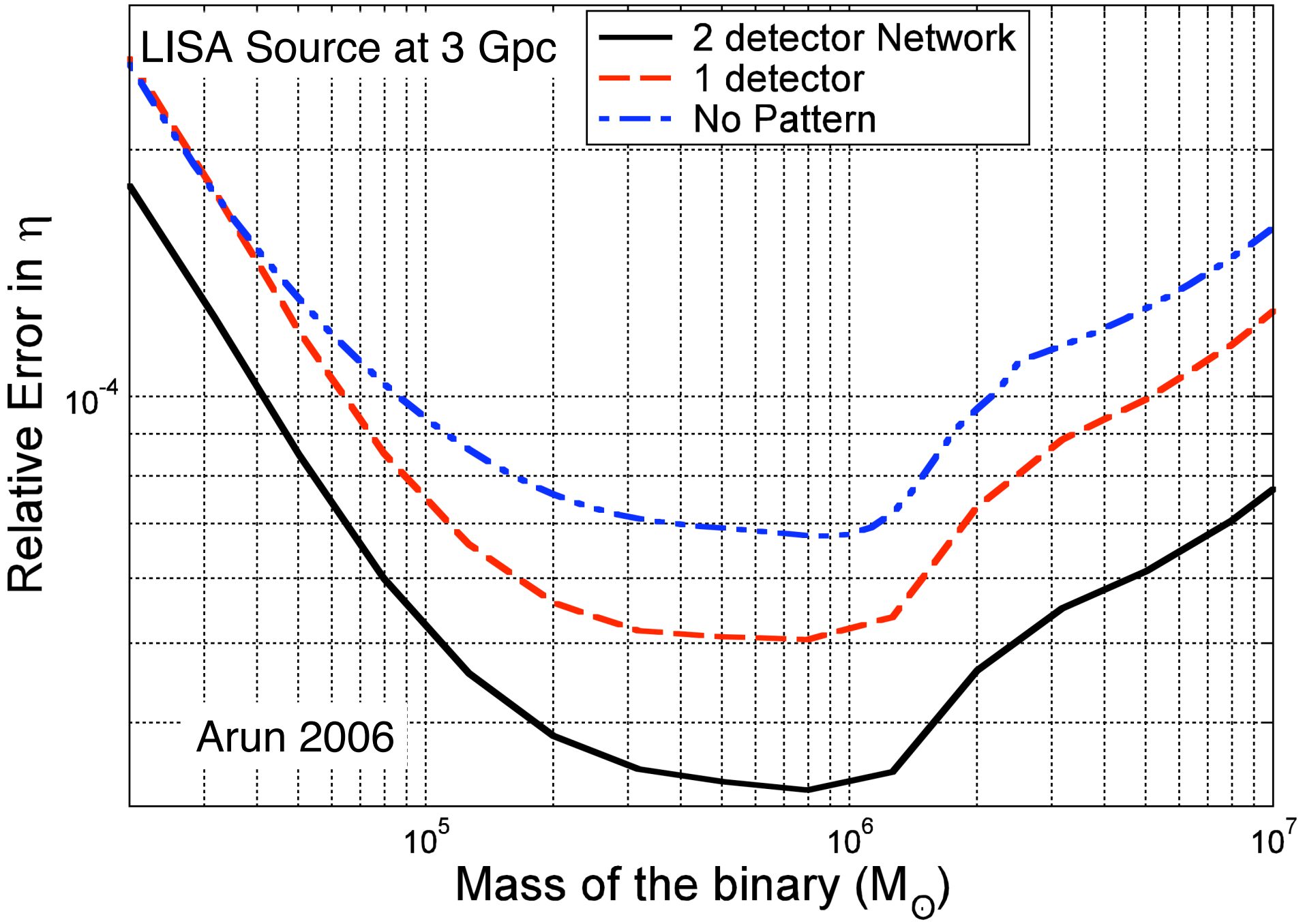
Overlap between different approximants more than 75%

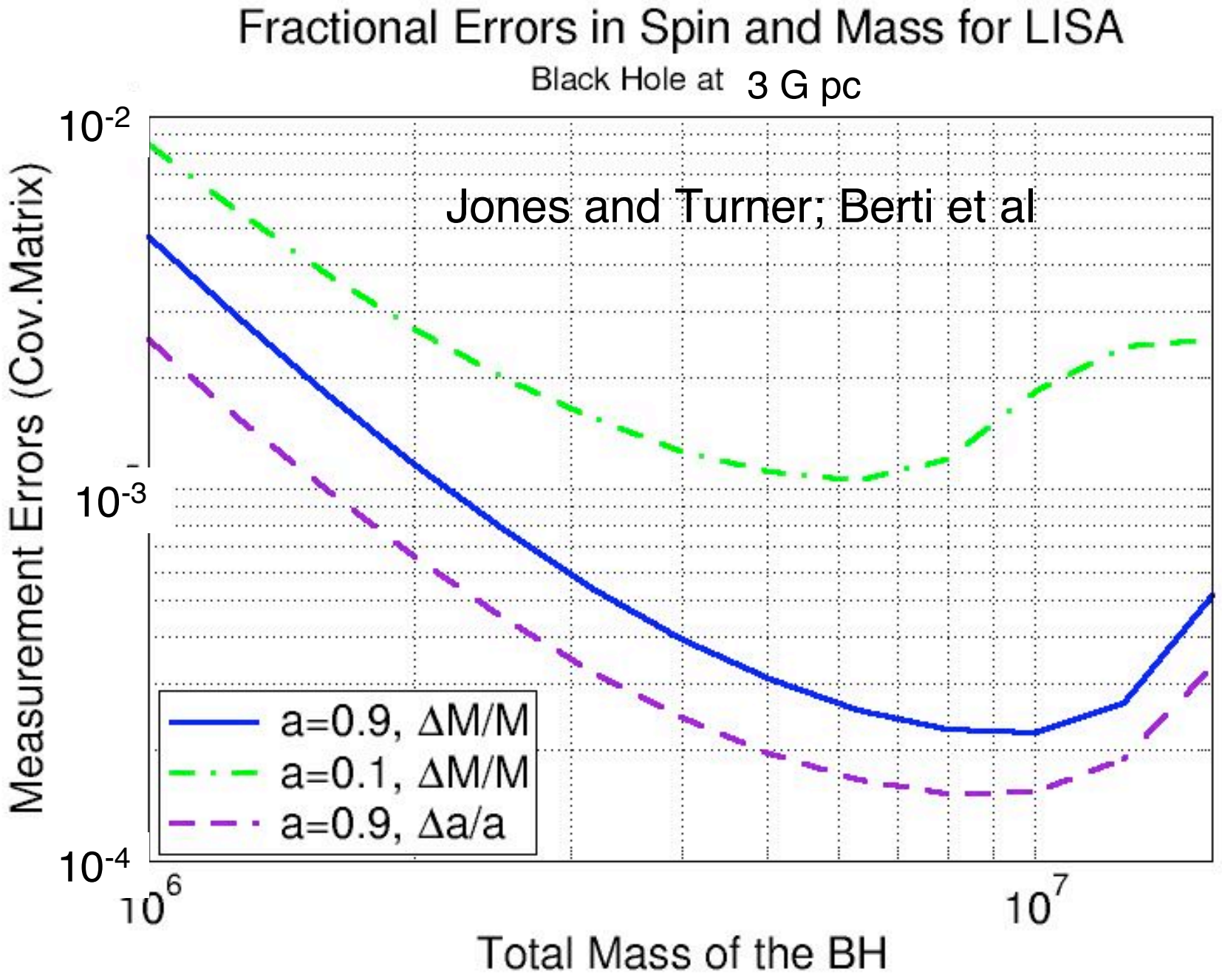
Accurate measurements from inspirals



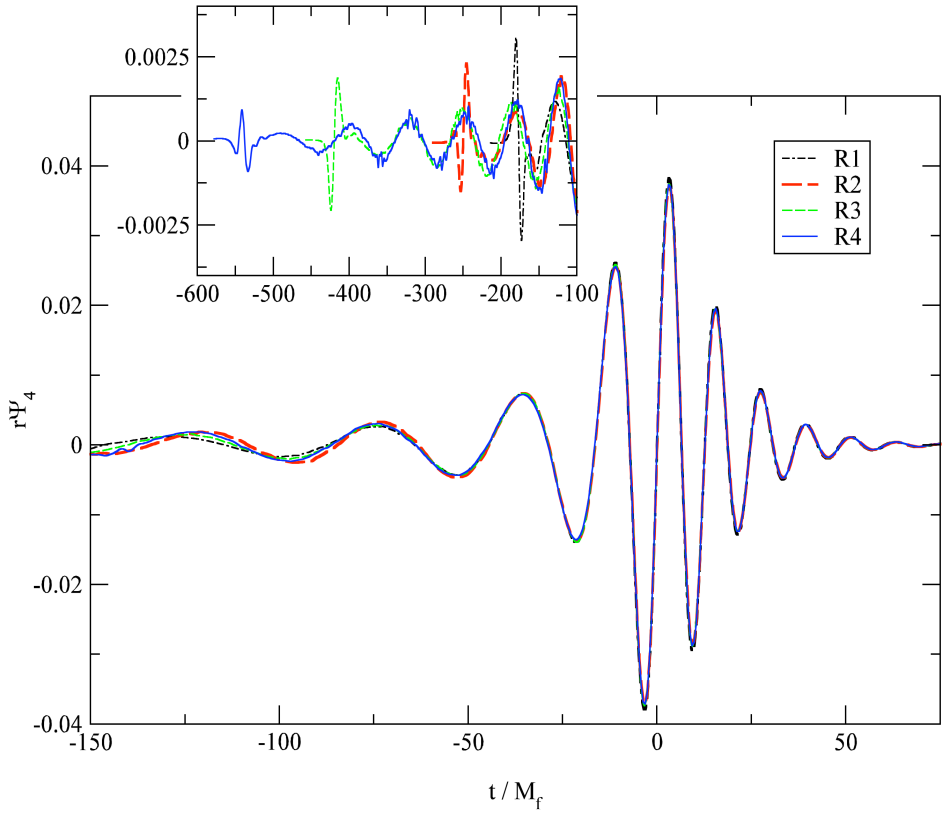

Fractional Errors in Mass and Spin for Advanced Ligo
Black Hole at 10Mpc
Measurement Errors (Cov. Matrix)
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
a=0.9, ΔM/M
a=0.1, ΔM/M
a=0.9, Δa/a
a=0.1, Δa/a
10^{1}
10^{2}
10^{3}
Total Mass of the BH


2 detector Network
1 detector
No Pattern
LISA Source at 3 Gpc
Arun 2006
Relative Error in Chirp mass
Mass of the binary ($M_\odot$)
10^{-5}
10^{-6}
10^5
10^6
10^7

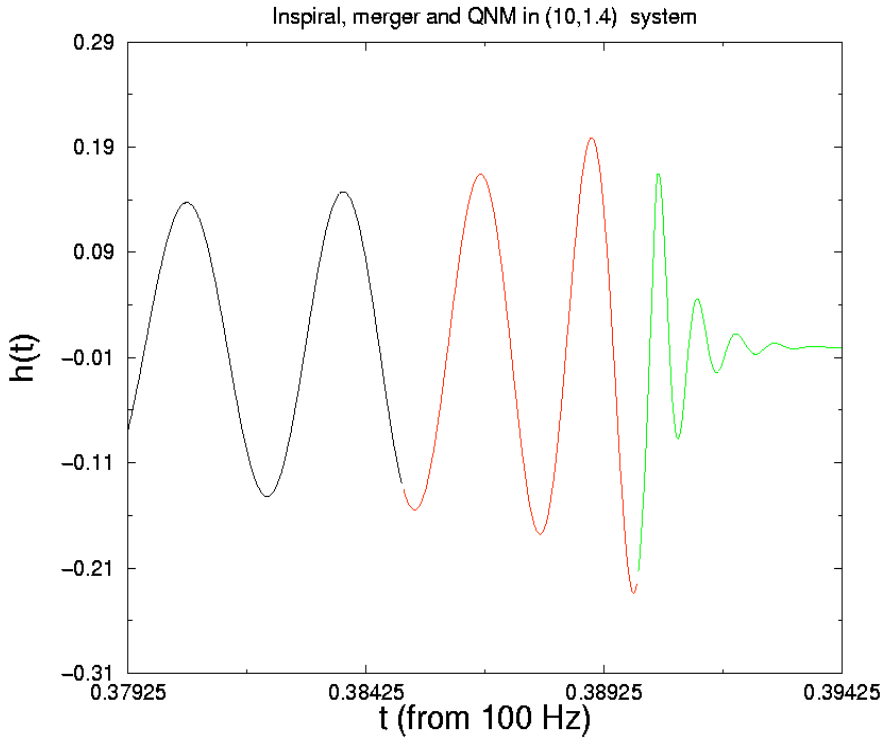

LISA Source at 3 Gpc
2 detector Network
1 detector
No Pattern
Relative Error in η
10^-4
Arun 2006
10^5
10^6
10^7
Mass of the binary (M_⊙)


Fractional Errors in Spin and Mass for LISA
Black Hole at 3 G pc
Jones and Turner; Berti et al
Measurement Errors (Cov.Matrix)
10-2
10-3
10-4
10^6
10^7
Total Mass of the BH
a=0.9, ΔM/M
a=0.1, ΔM/M
a=0.9, Δa/a

Analytical Vs Numerical Relativity

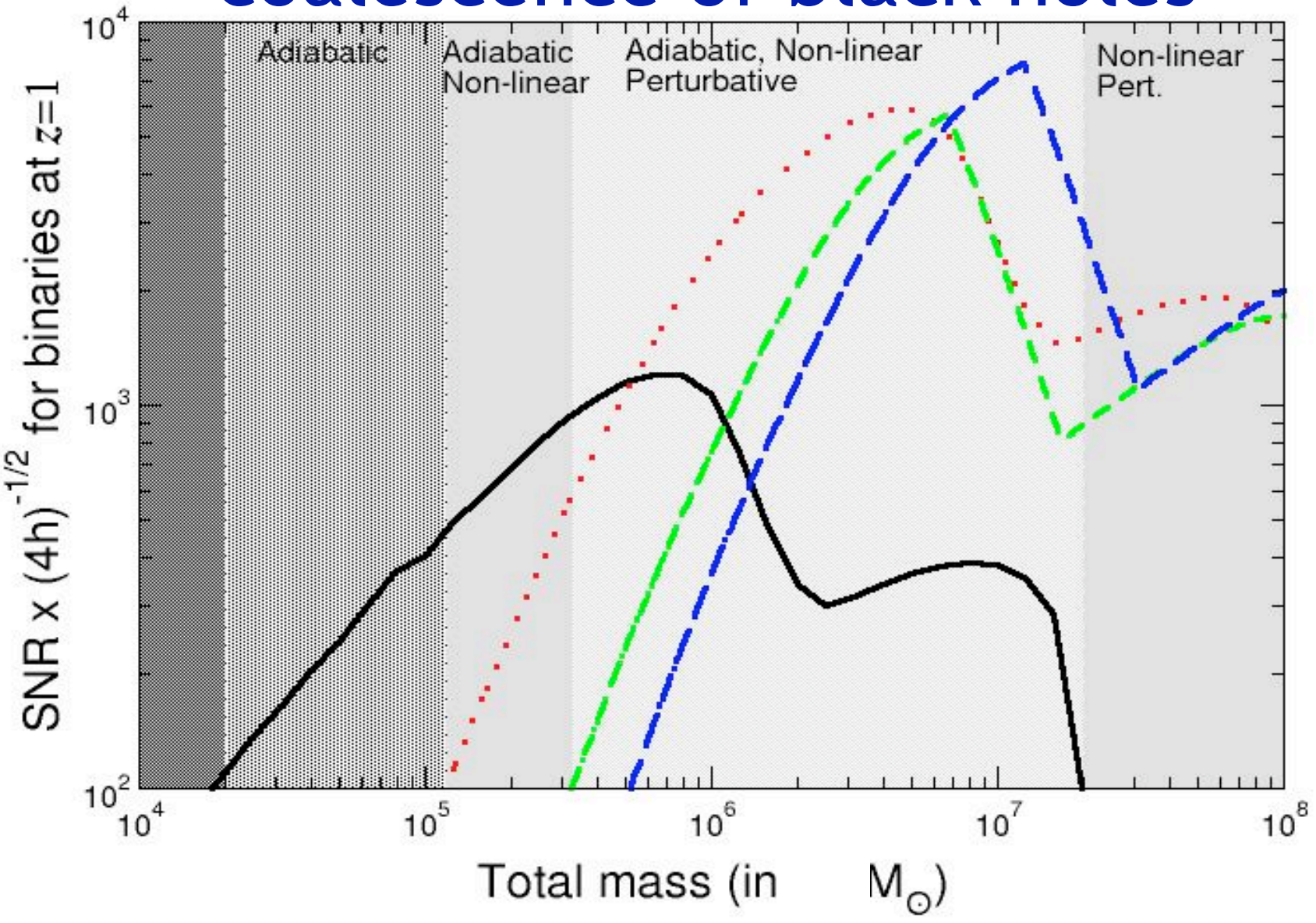


Baker et al



Buonanno and Damour

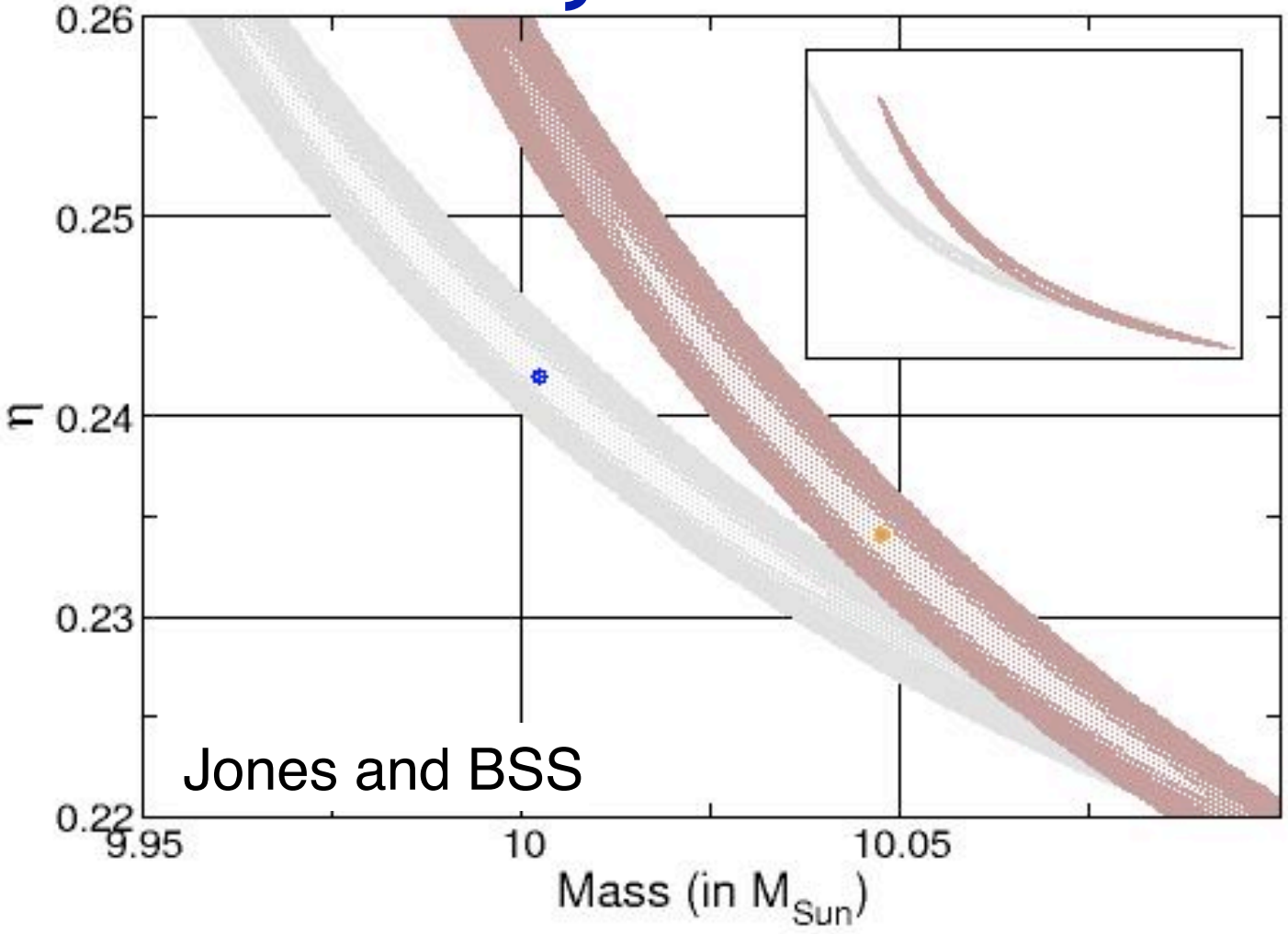
LISA SNR in different phases of coalescence of black holes



Bias in the Estimation is large

- Bias in the estimation is pretty small in the inspiral phase compared to systematic errors
- On using standard PN approximation to fit an EOB the bias is found to be larger than the expected systematic errors
- We still have to explore what happens with waveforms from NR

Strong field tests of gravity
Consistency of Parameters



Summary

- Use early "inspiral" epoch to reliably measure masses and spins
  - Small systematic errors compared to statistical errors
- From "ringdown" to extract a subset of parameters
  - Test for consistency between parameters from the inspiral and ringdown
- Fit the "merger" waveform from NR simulations
  - Does the fit agree with parameter estimation from the other two phases

Problems to think about

- There will be an inherent bias in the estimation of total mass before and after merger
  - The binary has lost about ~ few % of the total mass during merger and ringdown
  - The total mass determined from ringdown will be less than that from inspiral/merger